Monitoring Report
Lacamas Lake Annual Data Summary for 2005

Background

Since the original settlement of Clark County, land use changes have dramatically altered Lacamas Lake and resulted in conditions that reduce the lake's suitability for fishing, swimming, and aesthetic enjoyment. High nutrient inputs (primarily phosphorus but also nitrogen) from the watershed have been identified as a major contributing factor.

Ongoing problems include summertime dissolved oxygen depletion, poor water clarity, high levels of algae growth, nuisance blue-green algae blooms, and dense beds of aquatic plants.

Grant-funded activities implemented by Clark County and other agencies between 1987 and 2001 reduced agricultural phosphorus sources and increased public awareness of lake issues. Water quality monitoring indicated that phosphorus concentrations in the lake and its major tributary, Lacamas Creek, were substantially reduced during this period. Despite these improvements, however, water quality problems persist in Lacamas lake.

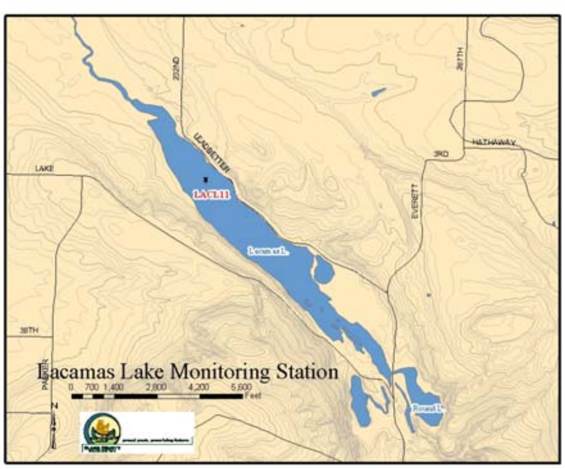
Since the conclusion of grant-funded work in 2001, Clark County Water Resources has continued routine monitoring of this resource to provide information for future lake management decisions.

This report summarizes monitoring activities and data collected from May through October 2005. Historical lake data and nutrient loading were most recently summarized following data collection in 2003. The April 2004 report Lacamas Lake Nutrient Loading and In-Lake Conditions may be viewed at http://www.clark.wa.gov/water-resources/documents.html. Summaries of grant-funded activities from 1987 through 1998 are also available.

Lake Description

Location

Lacamas Lake and Round Lake are located in Clark County, Washington, on the northern boundary of the city of Camas. Though named separately, Round Lake is part of Lacamas Lake connected by a small channel flowing under SE Everett Road. In a county with few lakes, Lacamas Lake is recognized as an important community resource. Fishermen, swimmers, boaters, and hikers utilize the lake and its shores year-round.



Size and morphology

Lacamas Lake is 2.4 miles long and has a maximum width of one quarter mile.

The lake is relatively deep, about 60 feet at its deepest, and covers approximately 330 acres. Water level is controlled by a dam originally constructed in the late 1800s to provide industrial water supply and a means to float logs to the mill in Camas.

Watershed
The Lacamas Creek watershed includes 67 square miles of forest, farm, residential, commercial, and industrial land. The Lacamas watershed extends from Hockinson in the north to Camas in the south. It's western border is approximately 162nd Avenue, and the eastern border is formed by Elkhorn and Livingston mountains (Clark County, 2004).

Lacamas Creek has five major tributaries: Matney Creek, Shanghai Creek, Fifth Plain Creek, China Ditch, and Dwyer Creek. There are also many smaller streams. Lacamas Creek flows about 12.5 miles, from relatively undisturbed forest headwaters through rural, agricultural, and residential areas, into Lacamas and Round Lakes. Below the lakes, Lacamas Creek drops through a series of waterfalls, and finally into the Washougal River (Clark County, 2004).

Monitoring activity summary

Methods
The details of the Lacamas Lake monitoring project are described in the project's quality assurance project plan (QAPP). Staff use standardized procedures for performing environmental measurements (Clark County, June 2002).

Monitoring is conducted on a monthly basis from May through October each year. Samples are collected at a single location over the deepest portion of the lake. This station has been utilized for monitoring since the early 1980s and provides a consistent location for long-term data collection.

Field measurements include vertical profiles for water temperature, dissolved oxygen, pH, and conductivity, as well as a single measurement of turbidity and Secchi depth. Water samples collected from the epilimnion (near the surface) and hypolimnion (near the bottom) are analyzed for total phosphorus, total Kjeldahl nitrogen, and nitrate + nitrite nitrogen. Chlorophyll *a* samples are obtained by compositing three grab samples equally spaced through the photic zone. The photic zone is the depth to which light penetrates, and is estimated as 2 times the measured Secchi depth.

Data management and analysis
Field observations and measurements are recorded with electronic field meters and backed up with hard copy forms. Field and analytical data are reviewed to ensure the data are complete and meet the quality control objectives for the project. Data are stored in hard-copy in three-ring binders until the completion of each sampling season, after which they are entered into the county's water quality database.

The level of data analysis and reporting varies according to a five-year schedule. Brief data summaries such as this one are produced following each sampling year. At the conclusion of the third year, a larger data report compiles and reports data from all three years. A technical report is completed following year five sampling, focusing on long-term trends in lake condition.

Data analysis focuses on the assessment of lake condition, specifically on the level of algal growth and related parameters. Basic summary statistics showing central tendency and variability of the data are calculated on seasonal datasets and summarized in tables. Data are also displayed using simple graphical techniques, such as time series and box-and-whisker plots.

A Trophic State Index (TSI) is used to describe the level of production of a lake, or the amount of algal matter produced by photosynthesis. Indices are used to integrate complex datasets, provide a common reference point to describe lake conditions, and help track changes over time. A single measurement of TSI does not indicate whether a lake's health is deteriorating, nor does it imply where a lake *should be* in terms of the current health.

Lake conditions

Based on a series of investigations dating back to the early 1980s, Lacamas and Round Lake are categorized as "eutrophic" (see Table 1 at the conclusion of this report for summary water quality values). The terms oligotrophic, mesotrophic, and eutrophic are often used to characterize lakes according to a low, medium, or high level of algal production, respectively. Over time, lakes naturally move slowly along this continuum in a direction toward eutrophic conditions (high algal production). In some cases, however, this movement can be dramatically accelerated due to human activities in a lake or watershed.

Trophic categories are not meant to convey value judgments. Oligotrophic conditions do not necessarily imply "good" water quality or a "healthy" lake. Conversely, eutrophic conditions do not always mean a lake is impaired or has "bad" water quality. Rather, trophic categories describe the amount of nutrient enrichment and biological productivity in a lake, whereas terms like "healthy" and "impaired" refer to the condition of a lake relative to its desired uses or natural condition (Snohomish County, 2003).

In the case of Lacamas Lake, accelerated eutrophication has dramatically altered the lake from its natural historical condition and resulted in conditions that may impair current desired uses such as fishing, swimming, and aesthetic enjoyment. Water quality monitoring during 2005 supports previous conclusions regarding the eutrophic condition of the lake.

Water clarity

Lacamas Lake has low water clarity. In general, an average summertime Secchi disk depth of less than 2.0 meters is indicative of eutrophic conditions. From May through October 2005, Secchi depth averaged 1.5 m and ranged from 1.1 to 2.1 m. Turbidity values were low to moderate, averaging 5.5 NTU and ranging from 2.3 to 9.0 NTU.

Secchi Disk

Water clarity in Lacamas Lake is impacted primarily by algal cells during the summer months. The lake often takes on a green tint when algal populations are high, and these algal blooms limit light penetration.

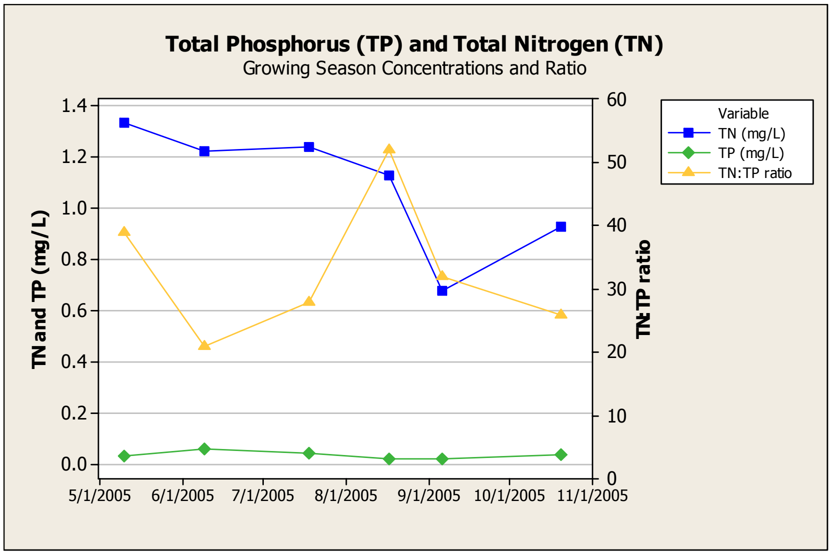
Nutrients

The total phosphorus criteria for preventing nuisance algal blooms and controlling eutrophication is 25 *ug*/L (EPA, 1986). Lacamas Lake had moderate phosphorus levels somewhat above this criterion throughout the summer, averaging 36 *ug*/L and ranging from 21 to 58 *ug*/L.

Total nitrogen concentrations were fairly high, averaging 1.09 *mg*/L and ranging from 0.93 to 1.34 *mg*/L.

The availability of nutrients to algae is an important aspect of nutrient levels in lakes. The ratio of TN to TP is often used to interpret the availability of nutrients relative to one another. Low ratios indicate an abundance of phosphorus and a relatively low amount of nitrogen. Higher ratios indicate a scarcity of phosphorus relative to nitrogen. In these cases we say that the nutrient in shorter supply is "limiting" algal growth. In some cases, the ratio may indicate the potential for either phosphorus or nitrogen to be limiting.

TN:TP ratios in the lake during 2005 were very high, ranging from 21 to 52, and indicated that phosphorus was the limiting factor for algal growth throughout the summer. This situation may have a positive impact on algal blooms because in a nitrogen-limited system nuisance blue-green algal species can have a competitive advantage.



(Above) Total Nitrogen (TN) and Total Phosphorus (TP) concentration and ratios, summer 2005

Oxygen/temperature

Vertical profiles of oxygen and temperature indicate that Lacamas Lake typically stratifies, or separates into layers by temperature. Stratification occurs when solar energy warms the surface water, while the deeper water tends to remain colder because the sun's rays only penetrate a short distance.

The resulting temperature gradient is often strong enough to confine water, nutrients, dissolved oxygen, and suspended materials to a discrete layer, playing a key role in the movement of materials within lakes.

Summer surface water temperatures are typically quite warm in Lacamas Lake. In 2005, temperatures reached nearly 24 degrees Celsius, about 75 degrees Fahrenheit. Temperatures in this range are sufficient to promote algal growth throughout the summer, and often favor certain species of algae, such as blue-green algae that may increase to nuisance levels. These temperatures are also considerably above the acceptable range for cold-water fish species such as trout. Suitable water temperatures were present throughout the summer at depths greater than 4-6 meters. However, these cold-water areas were often uninhabitable by fish due to extremely low dissolved oxygen concentrations.

Oxygen depletion results from the decomposition of biological material that settles to the lake bottom. Thermal stratification does not allow fresh oxygen from the atmosphere to reach the deeper layer and the oxygen is eventually depleted. The oxygen is only replenished when the thermocline breaks down and vertical mixing of the water column occurs during fall.

In Lacamas Lake there is generally insufficient oxygen for most aquatic life uses (<5 mg/L) at depths greater than 4-5 meters from June through October, with essentially no oxygen at all below 6 meters from July through September.

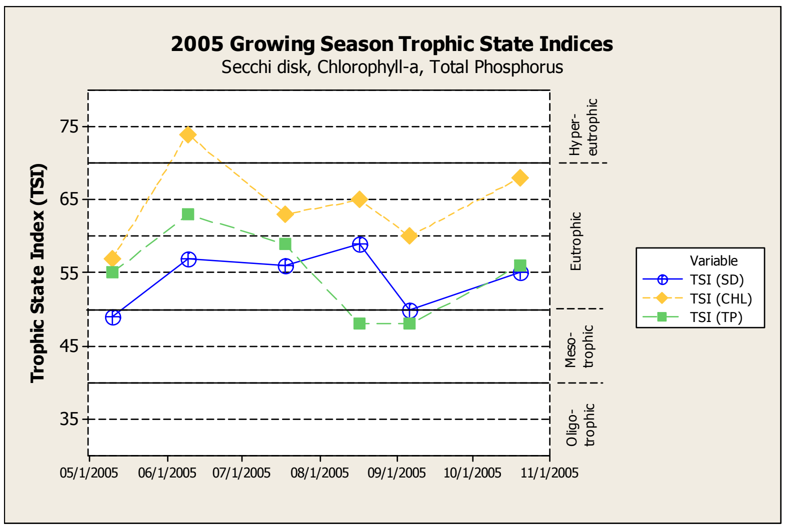
The combination of dissolved oxygen depletion in deeper cool water and elevated surface temperatures in shallower water forces fish and other aquatic life to survive in a very restricted, and sometimes non-existent, band of suitable habitat.

pH
Typically, aquatic life criteria require that pH levels remain neutral to slightly basic, not to exceed a value of 8.5-9.0 units (EPA, 1986). Lacamas Lake has relatively high pH levels and 2005 data indicated values were highest (~9.0 units) during July and August, most likely due to intense algal growth. By-products of the photosynthetic reactions in algal cells cause a net increase in pH.

Algae
Chlorophyll-a, a pigment present in algae that is used for photosynthesis, was used to estimate the amount of algae in the lake during 2005. The average chlorophyll-a concentration was 37 *ug*/L and ranged from 15 to 82 *ug*/L. Eutrophic lakes typically have maximum chlorophyll-a concentrations ranging between 20 and 200 *ug*/L (Holdren and others, 2001).

Algal cell counts were most recently performed in summer 2003. The phytoplankton community biovolume was dominated by species commonly associated with eutrophic conditions. The average biovolume and a general pattern of dominance by the diatom *Fragilaria crotonensis* and blue-green algal species were consistent with results from earlier studies in 1984 and 1995. However, a significant increase in the blue-green alga *Aphanizomenon flos-aquae* since 1984 is a likely indication of advancing eutrophication.

Trophic state
Trophic state indices (TSI) calculated from chlorophyll-a, Secchi disk, and total phosphorus values indicated that the lake was eutrophic, meaning the lake is enriched with nutrients and algae. The average TSI value for summer 2005 was 58 on a scale of 100, with individual values ranging from 48 to 74. Values between 50 and 70 are associated with eutrophic lakes.



(Above) Trophic State Index (TSI) values, summer 2005

Aquatic Plants
Lacamas Lake is characterized by extensive aquatic plant growth. Based on surface and scuba surveys, scientists in 1984 concluded that at least 97% of the potential colonizable area in Lacamas Lake was populated with aquatic plants. Results from the most recent WA Dept of Ecology survey in 1999 indicated increasing dominance of the plant community by Brazilian waterweed (*Egeria densa)*, an aggressive exotic species (photo). Since 1984, *Egeria densa* has largely displaced more desirable native species in the shallow-water areas (Parsons, 1999).

Egeria densa

Fish
The most recent Lacamas Lake fish population study was conducted in 1997 by the Washington Department of Fish and Wildlife. Lacamas Lake supports self-sustaining populations of warm-water fish (e.g. perch, bluegill, and bass).

The native cutthroat trout historically found in the lake are thought to be non-existent. Brown and rainbow trout are introduced through an annual stocking program and support a well-used fishery (Mueller and Downen, 1999).

The 1997 investigation concluded that warm-water species in Lacamas Lake exhibit signs of an unbalanced community, including slow growth, poor condition, and low recruitment. There appeared to be an overpopulation of small, slow growing fish with key size classes lacking.

Food availability did not appear to be a factor in causing the poor fish growth. Rather, the report concluded that poor water quality (primarily dissolved oxygen depletion) causes stress, limits habitat, and may be the greatest impediment to both the cold and warm-water fisheries (Mueller and Downen, 1999).

Summary

Overall conditions in Lacamas Lake were similar in 2005 to those observed over the past several years. Phosphorus levels were slightly higher than EPA's aquatic life criteria to avoid nuisance algal blooms, and nitrogen levels were relatively high. Elevated surface water temperatures combined with low dissolved oxygen conditions in the deeper areas limited summer cold-water fish habitat. Light penetration was consistently low due to abundant algal growth. Trophic state indices for Secchi disk, total phosphorus, and chlorophyll-a all indicated Lacamas Lake was eutrophic.

Algal growth was strongly phosphorus-limited during 2005, a change from recent years that have seen the lake shift to nitrogen limitation during late summer. The consistently elevated nitrogen values, compared with relatively low phosphorus inputs could indicate increased nitrogen sources in the watershed and/or an increased role of nitrogen in the ecology of Lacamas Lake.

Consistent limitation of algal growth by phosphorus could be a positive development for the lake, maintaining conditions favorable to desirable algal species. However, despite the limitation by phosphorus in 2005, current P levels are still easily sufficient to allow high levels of plant and algal growth and maintain a trophic status well into the eutrophic range.

Recommendations

Continued monitoring during the summer season is recommended to track long-term changes in lake condition and inform future management efforts. Renewed efforts to decrease phosphorus inputs to the lake could encourage consistent limitation by phosphorus. Successfully decreasing phosphorus inputs may help limit blue-green algal blooms and, if the decrease was significant enough, potentially move the lake toward a less eutrophic status.

Public and agency activities to improve Lacamas Lake have diminished since the major grant-funded restoration effort concluded in 2001. Renewed community interest and support would encourage further measures by state and local agencies to build on earlier successes in improving Lacamas Lake. Focused management efforts within the lake aimed at maintaining beneficial uses, such as mechanically introducing oxygen during the summer, would require consistent funding sources and broad public support.

In the absence of renewed lake and watershed management efforts, continuing human impacts to the lake are likely to erase past improvements and further degrade its beneficial uses.

Acknowledgements

Thank you to Clark County Public Works Water Resources staff for their assistance during 2005: Jason Wolf coordinated field activities and was assisted by Bob Hutton and Cary Armstrong.

For more information about Lacamas Lake water quality monitoring contact:

Jeff Schnabel
Clark County Water Resources
(360) 397-6118 ext. 4583
jeff.schnabel@clark.wa.gov

Or, visit the Clean Water Program website:
www.clark.wa.gov/water-resources/index.html

References

Clark County Public Works, Water Resources Section. June 2002. *Standard Procedures for Monitoring Activities*, Clark County Water Resources Section.

Clark County. 2004. Clark County Stream Health: A comprehensive overview of the condition of Clark County's streams, rivers, and lakes. Clark County Public Works, Clean Water Program, Vancouver Washington.

Holdren, C., W. Jones, and J. Taggart. 2001. Managing lakes and reservoirs. N. Am Lake Manage. Soc. And Terrene Inst., in cooperation with Off. Water Assess. Watershed Prot. Div. U.S. EPA, Madison, Wisconsin.

Mueller, K.W., and M.R. Downen. 1999. *1997 Lacamas Lake Survey: The Warmwater Fish Community of a Highly Eutrophic Lowland Lake.* Washington Department of Fish and Wildlife, Fish Program, Freshwater Division, Warmwater Enhancement Program, La Conner, Washington.

Parsons, J. 1999 Lacamas Lake aquatic plant summary. Washington Department of Ecology.

Schnabel, J.D. 2004. *Lacamas Lake Monitoring Project Quality Assurance Project Plan*. Clark County Public Works Water Resources, Vancouver, Washington.

Schnabel, J.D. April 2004. *Lacamas Lake Nutrient Loading and In-Lake Conditions*. Clark County Public Works Water Resources, Vancouver, Washington.

Snohomish County. 2003. *State of the Lakes Report*. Public Works, Surface Water Management.

United States Environmental Protection Agency. 1986. Quality Criteria for Water 1986. EPA 440/5-86-011, Office of Water Regulations an standards, Washington, DC.

Table 1. Average values for Lacamas Lake monitoring projects; values in parentheses are ranges for the period

Data Source	Date Range	Maximum Surface water temperature *(deg-C)*	Minimum water column oxygen concentration *(mg/L)*	Surface water pH *(units)*	Secchi Depth *(meters)*	Turbidity *(NTU)*	Total phosphorus *(mg/L-P)*	Total nitrogen *(mg/L-N)*	Chlorophyll-a *(ug/L)*
Beak and SRI, 1984	December 1983 to November 1984	23.2	<0.1	7.7 (6.6 - 9.4)	1.3 (0.6 – 2.0)	7.3	0.070	1.16	19 (0.4 – 65)
Clark County, 1994 (Lafer)	July 1991 to November 1992	23.0	<0.1	8.5 (7.5 – 9.6)	1.7	--	0.030 (0.015 – 0.063)	0.8 (0.4 – 1.6)	25 (est) 64 (max)
E&S, 1996	April to November, 1995	25.0	<0.1	7.9 (6.4 – 9.9)	1.4 (0.9 – 2.8)	4.3 (2.0 – 8.5)	0.041 (0.030 – 0.066)	1.13 (0.8– 1.4)	--
E&S, 1997	February to May, 1996	15.2	<0.1	6.4 (6.2 – 6.7)	1.1 (0.9 – 1.3)	6.8 (4.0 – 9.3)	0.102 (0.026 – 0.310)	1.5 (1.1 -1.9)	--
Clark County, 2000 (Schnabel)	October 1998 to September 1999	22.1	<0.1	7.5 (6.7 – 8.9)	1.6 (0.9 -2.1)	--	0.033 (0.018 – 0.050)	--	--
Clark County, 2002 (Schnabel)	October 1999 to September 2001	23.2	<0.1	--	1.4 (0.6 – 3.0)	--	0.030 (0.010 – 0.053)	1.2 (0.6 – 2.3)	--
Clark County, 2004 (Schnabel)	October 2001 to September 2003	25	<0.1	7.9 (6.8 – 9.3)	1.7 (0.5 – 3.0)	--	0.036 (0.010 – 0.079)	1.3 (0.4 – 2.4)	(May-Oct 2003 data unreliable)
Clark County (unpublished)	October 2003 to October 2004	24	<0.1	8.1 (6.9 – 9.0)	1.7 (1.2 – 2.5)	3.5	0.041 (0.023 – 0.144)	1.2 (0.5 – 2.2)	29 (18 – 35)
Clark County, 2006 (Schnabel)	May to October 2005	23.6	<0.1	8.6 (8.0 – 9.0)	1.5 (1.1 – 2.0)	6.0	0.036 (0.021 –0.058)	1.09 (0.7 – 1.3)	37 (15 – 82)